# Neighborhood's locality, walkability, and residents' multimorbidity: Evidence from the China's middle-aged and older population

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# Abstract

Background Neighborhood factors have gained increasing attention, while the role of neighborhood's walkability and location have not been clarified in multimorbidity. In this study, we estimated the prevalence of 14 non-communicable chronic disease (NCDs) and depicted variations in the number of NCDs as a function of road type, urban-rural settings, neighborhood characteristics, and individual confounders.

Methods Data came from China Health and Retirement Longitudinal Study 2011 National Baseline Survey. Negative binomial regression with clustered robust standard errors was employed to analyze variations in the number of NCDs among 13,414 Chinese middle-aged and older population.

Results First, over 65% subjects had at least one NCDs, and over 35% had multiple NCDs. Arthritis (33.08%), hypertension (24.54%), and digestive disease (21.98%) were the most prevalent NCDs. There existed no urban-rural differences in multimorbidity after adjusted for neighborhood clustering variations. Lastly, living with paved road was associated with fewer NCDs relative to living with unpaved road.

Conclusion Findings suggest that urban-rural disparities in the number of NCDs appeared to result from within-neighborhoods characteristics. Living with walkable road is important for middle-aged and older population.


# Background

Multimorbidity is the coexistence of two or more chronic diseases, which has gained increasing attention especially in the context of population aging (Banister 2012). Relative to younger generation, population aged over 60 has a higher proportion with chronic kidney disease (Zhang 2012), stoke (Teh et al. 2018), and heart disease (Moran et al. 2008), which are all major causes of deaths of the elderly (Couser et al. 2011). In particular, patients with multimorbidity have a higher probability of premature death (Menotti et al. 2001), longer hospital length of stay (Vogeli et al. 2007), functional disability (Fortin et al. 2004), and mental problems (McLean et al. 2014). Care for patients with multimorbidity is challenging, since most of current clinical guidelines are specific for single chronic diseases (Boyd et al. 2005; WHO 2016). In addition, multimorbidity requires patients to take multiple medications and have higher medication adherence, which is more difficult for older patients.

Prior observations have explored several individual-level attributes associated with multimorbidity. First, prior investigators note that multimorbidity is increasing with age (McLean et al. 2014; Violan et al. 2014). Women appear to have higher odds for multimorbidity relative to men (Violan et al. 2014). Lifestyle behaviors including smoke history (Menotti et al. 2001) and physical exercise (McLean et al. 2014), physiological attributes such as mental distress (McLean et al. 2014) and body mass index (Menotti et al. 2001), socioeconomic status like income and education status (Violan et al. 2014) are considered to be potential indicators of multimorbidity.

A fair number of observations suggest that urban residents have higher odds for being multimorbidity such as studies from Spain (Foguet-Boreu et al. 2014), Myanmar (Aye et al. 2019), and Korea (Yi et al. 2019). In contrast, a number of observations did not find the association between urban-rural disparities and multimorbidity such as a previous study from Portugal (Prazeres and Santiago 2015), and some studies even indicate that rural residents have higher probability of multimorbidity such as the one from Canada (Roberts et al. 2015). There are two relevant studies based on Chinese. One study did not directly introduce urban vs. rural settings in the model, thereby being unable to investigate urban-rural disparities after adjusting for variations in environment and socioeconomic inequality (Yi et al. 2019). In the other study, results suggest that urban residents have higher odds for multimorbidity, while investigators failed to include several important individuals' characteristics such as physical activity and BMI as well as environment variations in the study (Garin et al. 2015). Whether the urban-rural disparities indeed exist in China after controlling for neighborhood disparities and individuals' attributes is unclear.

Neighborhood factors that may affect health status have gained increasing attention. Hale et al. (2013) suggest that individual's perceived neighborhood quality such as perceptions of crime, litter, and pleasantness in the neighborhood may be associated with health status, and the link could be partially mediated by sleep quality. Steptoe and Feldman (2001) have demonstrated that lower neighborhood scores may be associated with psychological distress. Neighborhood's environmental attributes such as greenness and open space are recognized as space for walking for recreation and social coherence, which may lead to better mental and physical health (Sugiyama et al. 2008; Sugiyama et al. 2009). Other neighborhood attributes including socioeconomic status (Bethea et al. 2016; Bosma et al. 2001; Steptoe and Feldman 2004), access to public transport (Cummins et al. 2005), political climate (Cummins et al. 2005), street noise (Parra et al. 2010), and safety (Johnson et al. 2009; Ou et al. 2018) have been considered to be associated with residents' health status. Despite a significant number of studies focusing on the impact from neighborhood's environment and security on individuals' health (Cummins et al. 2005; Sugiyama et al. 2008; Sugiyama et al. 2009), a limited number of studies have investigated the association between walkability and older population's health status as a reflection of non-communicable chronic disease, care of which may be tremendously affected by neighborhood's walkability and access to health care.

To bridge the gaps, this study analyzed variations in health status for Chinese middle-aged and older population. Here, we offered two hypotheses for discussion. First, urban subjects may have more NCDs relative to rural subjects since they may live unhealthy life style and have a higher probability of exposure to air population (Steyn et al. 1997). Second, living with walkable road type, such as paved road, may be significantly associated with fewer NCDs since walkability may affect residents' access to health care particularly for population with limited mobility such as the elderly (Satariano et al. 2012).

# Methods

*Data source*

We derived data from China Health and Retirement Longitudinal Study (CHARLS) 2011 National Baseline Survey, which recorded data on 17,708 Chinese aged over 45 from 28 provinces in mainland China (Yang et al. 2012). Information regarding sampling, recruitment, response rate, and procedures for data collection could be retrieved from prior study (Yang et al. 2012). Excluding 4295 observations with missing data, we derived data on 13,413 subjects from 432 neighborhoods. In our definition, neighborhoods refer to villages in rural areas and communities in urban areas.

*Measures*

To measure health status, the overall number of non-communicable chronic diseases was calculated as the dependent variable. Whether a subject had ever been diagnosed with the fourteen non-communicable chronic diseases was recorded in the survey, the 14 non-communicable chronic diseases including hypertension, dyslipidemia, diabetes, cancer or malignant tumor, chronic lung diseases, chronic liver disease, heart problems, stroke, chronic kidney disease, stomach or other digestive disease, mental problems, memory-related disease, arthritis or rheumatism, and asthma. Data were derived from answers to the question *"Have you been diagnosed with the following 14 NCDs?".* In addition,the data on hypertension, chronic lung disease, and mental problems also included answers to the question "*Do you know if you have hypertension, chronic lung disease, and mental problems, respectively?".*

Neighborhood's walkability was reflected by road type. In this study, there were four types of road including unpaved road, paved road, sand-stone road and others. Urban versus rural setting was introduced to measure neighborhoods' locality and urbanization.

The number of primary care institutions in the neighborhood (community health centers, community health care medical posts, township health clinics, and village medical posts) were obtained to measure residents' access to primary care since prior studies have documented that access to health care resources could be associated with population health (Autier et al. 2011; Chen et al. 2010; Cossman et al. 2017). Data were derived from the question "*How many community health centers, community health care medical posts, township health clinics or village medical posts in the village or community?".* Last, water sanitation (groundwater system) was introduced to reflect neighborhood' living conditions.

Individual-level confounders including age, sex, marital status, education status, household income, body mass index (BMI), exercise, and health care insurance were introduced as covariates (Haas et al. 2003; Kuh et al. 2005; Trani et al. 2011). Health care insurance was classified as uninsured, rural cooperative medical insurance (RCMI), and others including business medical insurance, Urban Residents Medical Insurance, and Urban Employees Medical Insurance due to a limited number of subjects with the last three types of medical insurance in CHARLS.

*Statistical analysis*

First, we stratified study subjects into urban and rural groups to exam the distribution of the baseline characteristics (independent variables). Statistic tests including t test, Mann–Whitney U test, and Chi-squared test were employed according to data characteristics. The analysis was used for in-sample interpretations; thereby CHARLS survey weights were not used (table 1). For multimorbidity and prevalence of each NCD, CHARLS sampling weights were used for interpreting results as China's population representative parameters (table 2).

Next, negative binomial regression was employed instead of Poisson regression, since the dependent variable's variance was larger than its mean value. Univariate analysis was performed to examine disparities of NCDs as a function of each independent variable. Multivariate negative binomial regression analysis was employed with all covariates (Model1 in table 3). Clustered robust standard errors were generated in the model 2 to take individuals nested within neighborhoods into account. Variance inflation factors were calculated to exam collinearity among independent variables, which suggested slight collinearity. Models' significance was examined by Pearson chi-square.

In addition, we undertook sensitive analysis by performing a multinomial logistic regression with 5 responses (Y = 0, 1, 2, 3, and > or = 4) with robust standard errors. Results were qualitatively similar with those from negative binomial regression.

Statistical analyses were performed with Stata/SE 15.0 (StataCrop, TX, USA). A two-tailed P-value of less than 0.05 was considered statistically significant.

# Results

Table 1 presents the baseline descriptive characteristics for participants. We had 5639 urban subjects and 7774 rural subjects. Of the 13,413 participants, 3104 subjects (23.14%) lived with unpaved roads with 1001 subjects from urban areas (17.75%) and 2103 from rural areas (27.05%). There were 7.87% urban subjects and 13.07% rural subjects lived with sand-stone roads, and 74.00% urban subjects and 59.09% rural subjects relied on paved roads. Results from statistical test suggest that urban-rural disparities existed in road type (table 1). In addition, 24.05% subjects lived in neighborhoods without primary care institution, while 14.17% subjects lived with over three primary care institutions (table 1). Furthermore, 29.21% subjects lived with groundwater system, while over 70% subjects lived without groundwater system (table 1). A higher proportion of urban population (41.66%) lived with groundwater system relative to rural population (20.18%), which was statistically significant ($P < 0.001$). Last, individual-level attributes including household income, BMI, and exercise varied across urban and rural subjects (table 1).

# <Table 1 about here>

According to weighted analysis in table 2, over 65% study subjects had at least one NCDs, followed by 19.11% with two NCDs, 9.81% with three NCDs, and around 10% with at least 4 NCDs. The top 3 NCDs were arthritis or rheumatism (33.08%), hypertension (24.54%), and digestive disease (21.98%). In contrast, cancer, memory-related disease, and mental problems were the least prevalent NCDs. There were 0.90%, 1.45%, and 1.78% subjects self-reporting to have cancer, memory-related disease, and mental problems, respectively. Furthermore, there existed urban-rural disparities in the prevalence of hypertension, heart problems, dyslipidemia, diabetes, and asthma in unweighted statistical tests. Urban subjects were more likely to have hypertension, heart problems, dyslipidemia, and diabetes, whereas rural subjects had a greater probability of asthma ($P < 0.05$). After controlling for CHARLS sampling weights, there existed no urban-rural disparities in the prevalence of each NCD since the 95% CI of the proportion in urban residents overlapped with that in rural residents across all NCDs.

## <Table 2 about here>

Table 3 presents results from negative binomial. Results suggest that urban residents have a higher probability of more NCDs after controlling for all other covariates (Model 1 in Table 4, IRR = 1.05, 95% CI [1.01–1.09]). Results from model 2 that clustered individuals nested within neighborhoods, however, suggested that there existed no urban-rural disparities in the number of NCDs (IRR = 1.05, 95% CI [0.98–1.12]).

## <Table 3 about here>

Living with better road type was associated with fewer NCDs (table 3). Specifically, subjects living with paved roads (IRR = 0.87, 95% CI [0.83–0.91]) had significantly lower incident rate for more NCDs than those relying on unpaved roads after controlling for all covariates in model 1. Results were consistent after controlling for confounding within neighborhoods. (model 2 in table 3). Living with sand-stone road and other types of road was not consistently associated with NCDs across model 1 and model 2.

Living with more primary care institutions nearby were negatively associated with more NCDs (Table 3). Compared with those without primary care institutions in the neighborhood, subjects living with three primary care institutions or more were significantly less likely to have more NCDs (IRR = 0.90, 95% CI [0.85–0.96]). The disparities, however, did not exist after controlling for within-neighborhood variations (Model 2 in Table 3).

Last, two individual-level attributes, household income and BMI, were associated with NCDs (table 3). Specifically, the richest appeared to be less likely to suffer from a larger number of NCDs than the poorest (IRR = 0.93, 95% CI [0.89–0.98]), even after controlling for other covariates. Overweight (IRR = 1.16, 95% CI [1.08–1.24]) and obese subjects (IRR = 1.36, 95% CI [1.24–1.50]) had greater incident rate for more NCDs compared with those with BMI less than 18.5, even when other covariates were introduced. Subjects with BMI from18.5 to 25 had a lower probability of more NCDs relative to those BMI less than 18.5, even after controlling for all other covariates in model 1 (IRR = 0.91, 95%CI [0.85–0.97]).

## Discussion

By employing a national cohort of China's middle-aged and elder population, this study depicts the prevalence of multimorbidity and 14 NCDs among Chinese middle-aged and older population. Although prior studies have focused on the association between residents' walkability and mental health as well as quality of life (Sugiyama et al. 2008; Sugiyama et al. 2009), this study contributes to literature around the association between walkability and the middle-aged and the elderly's health status reflected by the number of NCDs, care of which may require pedestrian-friendly road to reach health services as well as social coherence. In contrast, we found that there existed no urban-rural disparities in residents' multimorbidity after controlling for within neighborhoods' variations.

Our results call for attention directed on non-communicable diseases in China. Relative to other society, the situation of non-communicable diseases in China is more urgent for its demographic shift and large population. According to our analysis, over 65% middle-age and the elderly had at least one NCDs and about 35% subjects had comorbidity, whereas prior observation in Canada concluded that around only 20% aged from 45 to 64 had comorbidity (Pefoyo et al. 2015). Results show that arthritis or rheumatism was the most prevalent NCDs, followed by hypertension and digestive disease. However, our study only includes observed NCDs, while neglecting those unobserved. One prior study, which analyzed data from medical questionnaire in CHARLS and included unobserved hypertension, suggested that there were around 40.9% subjects with hypertension (Feng XL 2014). Therefore, it is unwarranted to compare the prevalence of the 14 NCDs due to the exclusion of unobserved NCDs. However, results that Chinese middle-aged and elder population have a significant proportion with arthritis or rheumatism are consistent with a prior study (Zhang et al. 2001). Even though arthritis may not contribute to disease burden as considerably as hypertension and diabetes do (Yang et al. 2008), suffering from arthritis significantly impact elderly's mobility and quality of life (Badley and Wang 1998; Husted et al. 2001).

Our results offer some clues for urban-rural disparities in multimorbidity. Although urban population have a greater probability of encountering more NCDs relative to rural population (univariate analysis and model 1 in table 3), the differences appeared to be fully explained by within-neighborhood confounding. One possibility is that those with higher risk of multimorbidity, such as white collars that undertake greater life pressure, tend to be nested in several neighborhoods in urban cities. They may prefer to live closely to offices in order to save time to work, thereby forsaking their living conditions. It's unwarranted to compare our results (model 2 in table 3) with prior studies since most of them did not consider within-neighborhood variations. While our between-person results (model 1 in table 3) are consistent with results from Korea (Yi et al. 2019) and Spain (Foguet-Boreu et al. 2014), but differ from those in prior research from Canada (Roberts et al. 2015). The difference may result from disparities in living environment, occupation, and life behavior between two nations. Given the consistency and heterogeneity, urban-rural disparities in NCDs appear to vary across nations. Therefore, one should be careful to generalize ideas across nations of different social context. In particular, future analysis that derives data from national survey such as CHARLS should take within-neighborhood characteristics into account.

With reference to the second hypothesis, results confirm that living with walkable road was positively associated with individual's health status (table 4). Results here support findings from prior studies that living with pedestrian-friendly road type may be associated with the elderly's social coherence, mental health, and physical activity (Stafford et al. 2007; Sugiyama et al. 2008). While the other possibility is that walkability may link with access to primary care for the elderly. With a given number of primary care institutions in the neighborhood, population living with walkable road type had a lower probability of more NCDs (table 4), which is particularly important for patients with limited morbidity. For arthritis patients, the middle-aged, and the elderly, their morbidity may be limited and decrease over time (Satariano et al. 2012). Therefore, neighborhoods' walkability may affect their access to primary care, which may indirectly affect their probability of multimorbidity.

Three implications for policy makers or future analysis could be drawn from this study. First, although the prevalence of NCDs among Chinese older population has been extensively discussed, most of these studies focused on hypertension and diabetes (Yang et al. 2008). Therefore, we suggest that local government should pay more attention to the distribution of arthritis or rheumatism-related health resources and health education program. In addition, results in terms of urban-rural disparities were not consistent across models, which suggest that urban-rural disparities may link with within-neighborhood characteristics. Future studies may consider to take within-neighborhood variations into account. Last, our study suggests that government should consider local population's demographic characteristics and health demand, for example, the proportion of the elderly and their mobility. For population in transportation-disadvantaged regions such as rural areas in China's Tibet, Xinjiang, and Sichuan province, the distribution of health care resources should consider not only population density but also geographic attributes including land area, road type, and access to public transportation.

This study employed a good representative sample of Chinese middle-aged and older population with a large sample size. We depicted the prevalence of the 14 NCDs among Chinese middle-aged and older population. We analyzed variations in NCDs as a function of neighborhood attributes as well individual characteristics. We generated robust standard errors in multivariate models to capture within-neighborhood variations.

Despites the strength, this study has several limitations. First, the cross-sectional study design limited the potential to offer strong evidence for causality. Second, this study employed self-reported disease status, which may yield reporting bias and recalling bias. Moreover, CHARLS only recorded information of the 14 chronic diseases; thereby this study may underestimate the prevalence of multimorbidity. In addition, due to unavailable data, this study did not control for other living environment attributes, such as safety and green space, which may affect dwellers' health as well (Johnson et al. 2009; Sugiyama et al. 2008). Last, even though multimorbidity has gain increasing attention, it may not be an ideal measure of health status since it may not capture health variations among patients with the same number of NCDs as well as differences within various combination of concurrent NCDs.

# Abbreviations

NCDs, non-communicable chronic diseases.

CHARLS, China Health and Retirement Longitudinal Study.

BMI, body mass index.

RCMI, rural cooperative medical insurance.

IRR, incident rate ratio.

CI, confident interval

# References


Autier P, Boniol M, Gavin A, et al. Breast cancer mortality in neighbouring European countries with different levels of screening but similar access to treatment: trend analysis of WHO mortality database. BMJ. 2011; 343: 4411.

Aye SKK, Hlaing HH, Htay SS, et al. Multimorbidity and health seeking behaviours among older people in Myanmar: A community survey. PLoS One. 2019; 14(7): 0219543.

Badley EM and Wang PP. Arthritis and the aging population: projections of arthritis prevalence in Canada 1991 to 2031. J Rheumatol. 1998; 25(1): 138–44.

Banister J, Bloom DE, Rosenberg L. Population Aging and Economic Growth in China. In: Aoki M, Wu J. (eds) The Chinese Economy.International Economic Association Series. Palgrave Macmillan, London. 2012: 114–149.

Bethea TN, Palmer JR, Rosenberg L, et al. Neighborhood socioeconomic status in relation to all-cause, cancer, and Cardiovascular mortality in the black women's health study. Ethn Dis. 2016; 26(2): 157–64.

Bosma H, van de Mheen HD, Borsboom G J, et al. Neighborhood socioeconomic status and all-cause mortality. Am J Epidemiol. 2001; 153(4): 363–71.

Boyd CM, Darer, J, Boult, C, et al. Clinical Practice guidelines and quality of care for older patients with multiple comorbid diseases: Implications for pay for performance. JAMA. 2005; 294(6): 716–724.

Chen Z, Roy K, Haddix A C, et al. Factors associated with differences in mortality and self-reported health across states in the United States. Health Policy. 2010; 94(3): 203–10.

Cossman J, James W, and Wolf J K. The differential effects of rural health care access on race-specific mortality. SSM Popul Health. 2017; 3(618–623.

Couser WG, Remuzzi G, Mendis S, et al. The contribution of chronic kidney disease to the global burden of major noncommunicable diseases. Kidney Int. 2011; 80(12): 1258–70.

Cummins S, Stafford M, Macintyre S, et al. Neighbourhood environment and its association with self rated health: evidence from Scotland and England. J Epidemiol Community Health. 2005; 59(3): 207–13.

Feng XL, Pang M, Beard J. Health system strengthening and hypertension awareness, treatment and control: data from the China Health and Retirement Longitudinal Study. Bull World Health Organ 2014; 92

Foguet-Boreu Q, Violan C, Roso-Llorach A, et al. Impact of multimorbidity: acute morbidity, area of residency and use of health services across the life span in a region of south Europe. BMC Family Practice. 2014; 15(1): 55.

Fortin M, Lapointe L, Hudon, C, et al. Multimorbidity and quality of life in primary care: a systematic review. Health Qual Life Outcomes. 2004; 2(1):51.

Garin N, Koyanagi A, Chatterji S, et al. Global multimorbidity patterns: A cross-sectional, population-based, multi-country study. The Journals of Gerontology: Series A. 2015; 71(2): 205–214.

Haas JS, Lee LB, Kaplan CP, et al. The Association of Race, Socioeconomic Status, and Health Insurance Status With the Prevalence of Overweight Among Children and Adolescents. American Journal of Public Health. 2003; 93(12): 2105–2110.

Hale L, Hill TD, Friedman E, et al. Perceived neighborhood quality, sleep quality, and health status: evidence from the Survey of the Health of Wisconsin. Soc Sci Med. 2013; 79:16–22.

Husted JA, Gladman DD, Farewell VT, et al. Health-related quality of life of patients with psoriatic arthritis: A comparison with patients with rheumatoid arthritis. Arthritis Care & Research. 2001; 45(2): 151–158.

Johnson SL, Solomon BS, Shields WC, et al. Neighborhood Violence and its association with mothers' health: Assessing the relative importance of perceived safety and exposure to violence. Journal of Urban Health. 2009; 86(4): 538–550.

Kuh D, Bassey EJ, Wadsworth MEJ, et al. Grip strength, postural control, and functional leg power in a representative cohort of British men and women: Associations with physical activity, health status, and socioeconomic conditions. The Journals of Gerontology: Series A. 2005; 60(2): 224–231.

McLean G, Gunn J, Wyke S, et al. The influence of socioeconomic deprivation on multimorbidity at different ages: a cross-sectional study. The British journal of general practice: the journal of the Royal College of General Practitioners. 2014; 64(624): 440–447.

Menotti A, Mulder I, Nissinen A, et al. Prevalence of morbidity and multimorbidity in elderly male populations and their impact on 10-year all-cause mortality: The FINE study (Finland, Italy, Netherlands, Elderly). Journal of Clinical Epidemiology. 2001; 54(7): 680–686.

Moran A, Zhao D, Gu D, et al. The future impact of population growth and aging on coronary heart disease in China: projections from the Coronary Heart Disease Policy Model-China. BMC Public Health.

2008; 8(1): 394.

Ou JY, Peters JL, Levy JI, et al. Self-rated health and its association with perceived environmental hazards, the social environment, and cultural stressors in an environmental justice population. BMC Public Health. 2018; 18(1): 970.

Parra DC, Gomez LF, Sarmiento OL, et al. Perceived and objective neighborhood environment attributes and health related quality of life among the elderly in Bogota, Colombia. Soc Sci Med. 2010; 70(7): 1070–6.

Pefoyo AJ, Bronskill SE, Gruneir A, et al. The increasing burden and complexity of multimorbidity. BMC Public Health. 2015; 15: 415.

Prazeres F and Santiago L. Prevalence of multimorbidity in the adult population attending primary care in Portugal: a cross-sectional study. BMJ Open. 2015; 5(9): 009287.

Roberts KC, Rao DP, Bennett TL, et al. Prevalence and patterns of chronic disease multimorbidity and associated determinants in Canada. Health Promot Chronic Dis Prev Can. 2015; 35(6): 87–94.

Satariano WA, Guralnik JM, Jackson RJ, et al. Mobility and aging: new directions for public health action. Am J Public Health. 2012; 102(8): 1508–15.

Stafford M, Cummins S, Ellaway A, et al. Pathways to obesity: identifying local, modifiable determinants of physical activity and diet. Soc Sci Med. 2007; 65(9): 1882–97.

Steptoe A and Feldman PJ. Neighborhood problems as sources of chronic stress: Development of a measure of neighborhood problems, and associations with socioeconomic status and health. Annals of Behavioral Medicine. 2001; 23(3): 177–185.

Steptoe A and Feldman PJ. How neighborhoods and physical functioning are related: The roles of neighborhood socioeconomic status, perceived neighborhood strain, and individual health risk factors. Annals of Behavioral Medicine. 2004; 27(2): 91–99.

Steyn K, Kazenellenbogen JM, Lombard CJ, et al. Urbanization and the risk for chronic diseases of lifestyle in the black population of the Cape Peninsula, South Africa. Journal of Cardiovascular Risk. 1997; 4(2): 135–142.

Sugiyama T, Leslie E, Giles-Corti B, et al. Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? Journal of Epidemiology and Community Health. 2008; 62(5): e9-e9.

Sugiyama T, Thompson CW, and Alves S. Associations Between neighborhood open space attributes and quality of life for older people in Britain. Environment and Behavior. 2009; 41(1): 3–21.

Teh WL, Abdin E, Vaingankar JA, et al. Prevalence of stroke, risk factors, disability and care needs in older adults in Singapore: results from the WiSE study. BMJ Open. 2018; 8(3): 020285.

Trani J F, Browne J, Kett M, et al. Access to health care, reproductive health and disability: a large scale survey in Sierra Leone. Soc Sci Med. 2011; 73(10): 1477–89.

Violan C, Foguet-Boreu Q, Flores-Mateo G, et al. Prevalence, determinants and patterns of multimorbidity in primary care: a systematic review of observational studies. PLoS One. 2014; 9(7): e102149.

Vogeli C, Shields AE, Lee TA, et al. Multiple chronic conditions: prevalence, health consequences, and implications for quality, care management, and costs. J Gen Intern Med. 2007; 22 Suppl 3(391–5.

WHO. Multimorbidity: Technical series on safer primary care. 2016.

Yang G, Kong L, Zhao W, et al. Emergence of chronic non-communicable diseases in China Lancet. 2018; 372:1697–1705

Yang G, Smith JP, Strauss J, et al. Cohort Profile: The China Health and Retirement Longitudinal Study (CHARLS). International Journal of Epidemiology. 2012; 43(1): 61–68.

Yi JY, Kim H, and Chi I. Urban-rural differences in multimorbidity and associated factors in China and Korea: A population-based survey study. Geriatr Gerontol Int. 2019.

Zhang L, Wang F, Wang L, et al. Prevalence of chronic kidney disease in China: a cross-sectional survey. Lancet. 2012; 379(379): 815–822.

Zhang Y, Xu L, Nevitt MC, et al. Comparison of the prevalence of knee osteoarthritis between the elderly Chinese population in Beijing and whites in the United States: The Beijing osteoarthritis study. Arthritis & Rheumatism. 2001; 44(9): 2065–2071.

# Tables

Table 1 Baseline characteristics (N=13413)

| | All (N=13413) | | urban (N=5639) | | Rural (N=7774) | | *P* value [a] |
|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | |
| road type | | | | | | | |
| unpaved road | 3104 | 23.14 | 1001 | 17.75 | 2103 | 27.05 | <0.0001 |
| paved road | 8767 | 65.36 | 4173 | 74.00 | 45943 | 59.09 | |
| sand-stone road | 1460 | 10.88 | 444 | 7.87 | 1016 | 13.07 | |
| other | 82 | 0.61 | 21 | 0.37 | 21 | 0.37 | |
| primary care institutions | | | | | | | 0.07 |
| 0 | 3226 | 24.05 | 1333 | 23.64 | 1893 | 24.35 | |
| 1 | 5188 | 38.68 | 2210 | 39.19 | 2978 | 38.31 | |
| 2 | 3098 | 23.10 | 1339 | 23.75 | 1759 | 22.63 | |
| ≥3 | 1901 | 14.17 | 757 | 13.42 | 1144 | 14.72 | |
| underground water | | | | | | | <0.0001 |
| no | 9495 | 70.79 | 3290 | 58.34 | 6205 | 79.82 | |
| yes | 3918 | 29.21 | 2349 | 41.66 | 1569 | 20.18 | |
| sex | | | | | | | 0.13 |
| male | 6431 | 47.95 | 2660 | 47.17 | 3771 | 48.51 | |
| female | 6982 | 52.05 | 2979 | 52.83 | 4003 | 51.49 | |
| age | 59.09 (±10.16)* | | 58.91 (±10.14)* | | 59.21 (±10.18)* | | <0.0001 |
| marital status | | | | | | | 0.08 |
| married | 10741 | 80.08 | 4475 | 79.36 | 6266 | 80.60 | |
| other | 2672 | 19.92 | 1164 | 20.64 | 1508 | 19.40 | |
| education status | | | | | | | 0.67 |
| illiteracy | 3672 | 27.38 | 1543 | 27.36 | 2129 | 27.39 | |
| below primary school | 2371 | 17.68 | 1019 | 18.07 | 1352 | 17.39 | |
| primary school | 2895 | 21.58 | 1195 | 21.19 | 1700 | 21.87 | |
| junior school or above | 4475 | 33.36 | 1882 | 33.37 | 2593 | 33.35 | |
| household income(quartile) | | | | | | | <0.0001 |
| 1st(the poorest) | 3218 | 23.99 | 1477 | 26.19 | 1741 | 22.40 | |
| 2nd | 3466 | 25.84 | 1363 | 24.17 | 2103 | 27.05 | |
| 3rd | 3345 | 24.94 | 1418 | 25.15 | 1927 | 24.79 | |
| 4th(the richest) | 3384 | 25.23 | 1381 | 24.49 | 2003 | 25.77 | |
| body mass index (kg/m$^2$) | | | | | | | <0.001 |
| <18.5 | 935 | 6.97 | 358 | 6.35 | 577 | 7.42 | |
| ≥18.5 and <25 | 8362 | 62.34 | 3449 | 61.16 | 4913 | 63.20 | |
| ≥25 and <30(overweight) | 3462 | 25.81 | 1532 | 27.17 | 1930 | 24.83 | |
| ≥30(obese) | 654 | 4.88 | 300 | 5.32 | 354 | 4.55 | |
| health care insurance | | | | | | | 0.14 |
| uninsured | 893 | 6.66 | 375 | 6.65 | 518 | 6.66 | |
| RCMI | 9771 | 72.85 | 4063 | 72.05 | 5708 | 73.42 | |
| others | 2749 | 20.50 | 1201 | 21.30 | 1548 | 19.91 | |
| exercise | | | | | | | <0.0001 |
| never | 12686 | 94.58 | 5144 | 91.22 | 7542 | 97.02 | |
| seldom | 112 | 0.84 | 75 | 1.33 | 37 | 0.48 | |
| a weekly basis | 129 | 0.96 | 88 | 1.56 | 41 | 0.53 | |
| a daily basis | 486 | 3.62 | 332 | 5.89 | 154 | 1.98 | |

Note:

* represents mean ( ± standard deviation).

[a] T test was employed for age , Mann–Whitney U test was employed for primary care institutions, education status, household income, body mass index, and exercise. Chi-squared test was employed for road type, groundwater system, sex, marital status, and health care insurance.

CI, confident interval.

BMI, body mass index.

RCMI,  rural cooperative medical insurance.

Table 2 Multimorbidity among China’s middle-aged and the elder participants (N=13,413)

| Characteristics | Unweighted sample, N (%) | | | Weighted to reflect to China's population, % (95 CI) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | All (N =13,413) | Urban (N = 5,639) | Rural (N=7,774) | All | | Urban | | Rural | |
| Chronic disease | | | | | | | | | |
| 0 | 4216 (31.43) | 1730 (30.68) | 2486 (31.98) | 32.09 | (28.97-34.11) | 32.61 | (30.62 - 34.67) | 31.48 | (30.50 - 33.72) |
| 1 | 4020 (29.97) | 1665 (29.53) | 2355 (30.29) | 30.58 | (28.73-32.57) | 30.55 | (29.25 - 31.89) | 30.62 | (29.46 - 31.73) |
| 2 | 2648 (19.74) | 1146 (20.32) | 1502 (19.32) | 19.11 | (17.89 - 21.28) | 18.75 | (17.65 - 19.90) | 19.53 | (18.14 - 20.12) |
| 3 | 1393 (10.39) | 586 (10.39) | 807 (10.38) | 9.81 | (8.58 - 10.62) | 10.04 | (9.19 - 10.95) | 9.55 | (9.16 - 10.50) |
| 4 | 680 (5.07) | 310 (5.5) | 370 (4.76) | 4.82 | (4.17 - 6.07) | 4.64 | (4.08 - 5.28) | 5.04 | (4.31 - 5.39) |
| 5 | 304 (2.27) | 131 (2.32) | 173 (2.23) | 2.25 | (1.61 - 2.72) | 2.39 | (1.95 - 2.92) | 2.10 | (1.92 - 2.65) |
| 6 | 97 (0.72) | 46 (0.82) | 51 (0.66) | 0.93 | (0.69 - 2.25) | 0.65 | (0.47 - 0.91) | 1.25 | (0.62 - 1.38) |
| 7 | 37 (0.28) | 17 (0.3) | 20 (0.26) | 0.27 | (0.17 - 0.54) | 0.24 | (0.14 - 0.42) | 0.31 | (0.18 - 0.40) |
| 8 | 12 (0.09) | 5 (0.09) | 7 (0.09) | 0.09 | (0.03 - 0.21) | 0.09 | (0.04 - 0.22) | 0.08 | (0.05 - 0.16) |
| 9 | 4 (0.03) | 2 (0.04) | 2 (0.03) | 0.03 | (0.01 - 0.12) | 0.03 | (0.01 - 0.12) | 0.03 | (0.01 - 0.08) |
| 10 | 2 (0.01) | 1 (0.02) | 1 (0.01) | 0.02 | (0.00 - 0.16) | 0.01 | (0.00 - 0.08) | 0.02 | (0.00 - 0.07) |
| arthritis or rheumatism | 4570 (34.07) | 1923 (34.1) | 2647 (34.05) | 33.08 | (31.29 - 34.93) | 32.87 | (30.59 - 35.24) | 33.33 | (30.53 - 36.25) |
| hypertension | 3276 (24.42) | 1453 (25.77) | 1823 (23.45) | 24.54 | (22.85 - 26.31) | 23.69 | (21.91 - 25.58) | 25.53 | (22.55 - 28.75) |
| digestive disease | 3083 (22.99) | 1251 (22.18) | 1832 (23.57) | 21.98 | (20.68 - 23.33) | 22.69 | (21.24 - 24.21) | 21.15 | (18.92 - 23.56) |
| heart problems | 1538 (11.47) | 728 (12.91) | 810 (10.42) | 11.21 | (10.23 - 12.27) | 10.18 | (9.05 - 11.45) | 12.41 | (10.79 - 14.23) |
| chronic lung diseases | 1616 (12.05) | 688 (12.2) | 928 (11.94) | 11.82 | (10.99 - 12.71) | 11.89 | (10.84 - 13.03) | 11.74 | (10.45 - 13.18) |
| dyslipidemia | 1162 (8.66) | 535 (9.49) | 627 (8.07) | 8.86 | (7.99 - 9.81) | 8.21 | (7.12 - 9.45) | 9.62 | (8.28 -11.14) |
| chronic kidney disease | 833 (6.21) | 324 (5.75) | 509 (6.55) | 5.96 | (5.34 - 6.64) | 6.48 | (5.58 - 7.52) | 5.35 | (4.57 - 6.25) |
| diabetes | 743 (5.54) | 356 (6.31) | 387 (4.98) | 5.85 | (5.24 - 6.52) | 5.14 | (4.45 - 5.93) | 6.67 | (5.67 - 7.83) |
| Chronic liver disease | 521 (3.88) | 224 (3.97) | 297 (3.82) | 3.90 | (3.44 - 4.43) | 3.79 | (3.23 - 4.45) | 4.03 | (3.32 - 4.90) |
| asthma | 511 (3.81) | 206 (3.65) | 305 (3.92) | 3.69 | (3.26 - 4.17) | 3.97 | (3.41 - 4.62) | 3.36 | (2.75 - 4.11) |
| stroke | 407 (3.03) | 197 (3.49) | 210 (2.7) | 2.17 | (1.83 - 2.57) | 2.00 | (1.58 - 2.52) | 2.37 | (1.84 - 3.03) |
| mental problems | 258 (1.92) | 111 (1.97) | 147 (1.89) | 1.78 | (1.48 - 2.14) | 1.79 | (1.40 - 2.28) | 1.77 | (1.34 - 2.34) |
| memory-related disease | 177 (1.32) | 84 (1.49) | 93 (1.2) | 1.45 | (1.16 - 1.80) | 1.43 | (1.08 - 1.89) | 1.47 | (1.03 - 2.08) |
| cancer | 132 (0.98) | 51 (0.9) | 81 (1.04) | 0.90 | (0.74 - 1.09) | 1.03 | (0.82 - 1.30) | 0.74 | (0.52 - 1.04) |

Note: CI, confident interval.

Table 3 Negative binomial regression analysis of multimorbidity (N=13,413)

| Independent variable | Univariate analysis | | Model 1 | | Model 2 [a] | |
|---|---|---|---|---|---|---|
| | IRR | 95% CI | IRR | 95 %CI | IRR | 95 %CI |
| **Neighborhood-level** | | | | | | |
| road type | | | | | | |
| unpaved road | reference | | reference | | reference | |
| others | 1.24* | (1.02 - 1.51) | 1.15 | (0.95 - 1.41) | 1.15* | (1.04 - 1.27) |
| paved road | 0.88*** | (0.85 - 0.92) | 0.87*** | (0.83 - 0.91) | 0.87*** | (0.80 - 0.95) |
| sand-stone road | 0.91** | (0.85 - 0.97) | 0.92** | (0.86 - 0.97) | 0.92 | (0.80 - 1.05) |
| urban (vs rural) | 1.00* | (1.00 - 1.00) | 1.05** | (1.01 - 1.09) | 1.05 | (0.98 - 1.12) |
| primary care institutions | | | | | | |
| 0 | reference | | reference | | reference | |
| 1 | 0.99 | (0.95 - 1.03) | 0.99 | (0.95 - 1.04) | 0.99 | (0.91 - 1.08) |
| 2 | 0.99 | (0.94 - 1.04) | 1.00 | (0.95 - 1.05) | 1.00 | (0.90 - 1.10) |
| ≥3 | 0.90** | (0.85 - 0.96) | 0.94* | (0.89 - 1.00) | 0.94 | (0.84 - 1.06) |
| groundwater system | | | | | | |
| yes (vs no) | 1.00 | (0.96 - 1.04) | 1.00 | (0.96 - 1.05) | 1.00 | (0.93 - 1.08) |
| **Individual-level confounders** | | | | | | |
| age( in a unit of ten years) | 1.00 | (0.98 - 1.01) | 0.99 | (0.97 - 1.01) | 0.99 | (0.97 - 1.01) |
| female (vs male) | 1.00 | (0.96 - 1.03) | 1.00 | (0.96 - 1.04) | 1.00 | (0.96 - 1.04) |
| married (vs others) | 0.97 | (0.93 - 1.02) | 0.97 | (0.93 - 1.01) | 0.97 | (0.93 - 1.01) |
| household income | | | | | | |
| 1st (the poorest) | reference | | reference | | reference | |
| 2nd | 1.03 | (0.98 - 1.07) | 1.03 | (0.98 - 1.08) | 1.03 | (0.98 - 1.08) |
| 3rd | 0.96 | (0.91 - 1.00) | 0.96 | (0.93 - 1.00) | 0.96 | (0.91 - 1.01) |
| 4th (the richest) | 0.94* | (0.89 - 0.99) | 0.93** | (0.89 - 0.98) | 0.93* | (0.88 - 0.99) |
| education status | | | | | | |
| illiteracy | reference | | reference | | reference | |
| below primary school | 1.03 | (0.97 - 1.08) | 1.03 | (0.97 - 1.08) | 1.03 | (0.98 - 1.08) |
| primary school | 1.01 | (0.96 - 1.06) | 1.01 | (0.96 - 1.06) | 1.01 | (0.96 - 1.07) |
| junior school or above | 1.03 | (0.99 - 1.07) | 1.03 | (0.98 - 1.09) | 1.03 | (0.98 - 1.08) |
| health care insurance | | | | | | |
| uninsured | reference | | reference | | reference | |
| RCMI | 1.03 | (0.96 - 1.10) | 1.03 | (0.96 - 1.11) | 1.03 | (0.96 - 1.11) |
| others | 1.04 | (0.96 - 1.12) | 1.06 | (0.98 - 1.15) | 1.06 | (0.98 - 1.15) |
| body mass index | | | | | | |
| <18.5 | reference | | reference | | reference | |
| ≥18.5 and <25 | 0.91* | (0.85 - 0.97) | 0.91** | (0.85 - 0.97) | 0.91** | (0.85 - 0.97) |
| ≥25 and <30 | 1.15*** | (1.08 - 1.24) | 1.16*** | (1.08 - 1.24)) | 1.16*** | (1.08 - 1.25) |
| ≥30 | 1.36*** | (1.24 - 1.50) | 1.36*** | (1.24 - 1.50) | 1.36*** | 1.24 - 1.50) |
| exercise | | | | | | |
| never | reference | | reference | | | |
| seldom | 1 | (0.83 - 1.21) | 1 | (0.83 - 1.20) | 1.00 | (0.83 - 1.20) |
| a weekly basis | 1.09 | (0.92 - 1.29) | 1.09 | (0.92 - 1.29) | 1.09 | (0.90 - 1.32) |
| a daily basis | 1.10* | (1.01 - 1.20) | 1.08 | (0.99 - 1.18) | 1.08 | (0.96 - 1.21) |

Note: *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$.

[a] standard errors were adjusted for clusters within neighborhoods

BMI, body mass index.

RCMI, rural cooperative medical insurance.

IRR, incident rate ratio.

CI, confident interval.